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TRANSLATION OF ARTICLE 34 AMENDMENTS

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New Description Pages

It is also a known procedure to configure independent spherical semiconductor elements that constitute complete semiconductors, including the requisite electrodes. For example, European patent application EP 0 940 860 A1 describes using a spherical core to make a spherical semiconductor element by means of masking, etching steps and the application of various material layers. Such semiconductor elements can be used as solar cells if the p-n junction is selected in such a way that it can convert incident light into energy. If the p-n junction is configured in such a way that it can convert an applied voltage into light, then the semiconductor element can be employed as a light-emitting element.

In view of the wide array of envisaged areas of application for such semiconductor elements, the elements have to be completely independent components with electrode connections that can be installed in other applications. This calls for a high complexity of the semiconductor elements and of the requisite production processes. Due to the small dimensions amounting to a few millimeters on the part of the spherical shapes employed, the production of the spherical elements with all of the function layers and processing steps is very expensive.

Moreover, U.S. Pat. No. 5,578,503 discloses a method for the rapid production of chalcopyrite semiconductor layers on a substrate in which individual layers of the elements copper, indium or gallium and sulfur or selenium are applied onto a substrate in elemental form or as a binary interelemental compound. The substrate with

the layer structure is then quickly heated up and kept at a temperature of $\geq 350^{\circ}\text{C}$ [$\geq 662^{\circ}\text{F}$] for between 10 seconds and one hour.

Moreover, U.S. Pat. No. 4,173,494 describes a semiconductor system with spherical semiconductors that are incorporated into a glass layer. The spherical elements protrude from the surface of the layer on both sides of the glass layer, whereby on one side, a metal layer is applied that joins all of the elements to each other. The spherical elements have a surface consisting of one conductor type and a core of

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the opposite conductor type. Thus, some elements have a core made of a material of the p-type, whereas other elements have a core made of a material of the n-type, resulting in p-n spheres and n-p spheres. Such semiconductor systems are especially well-suited for use in solar cells.

The objective of the invention is to provide a semiconductor element having a high activity that is suitable for flexible use in various solar cells.

The objective of the invention is also to provide an efficient method for the production of a semiconductor element for use in solar cells.

Another objective of the invention is to provide a method for incorporating a semiconductor element into a solar cell.

It is likewise the objective of the invention to provide a solar cell having integrated semiconductor elements and a photovoltaic module having at least one solar cell.

According to the invention, this objective is achieved by the features of the main claims 1, 10, 21, 28 and 40. Advantageous refinements of the invention can be gleaned from the subordinate claims.

According to the invention, the objective is achieved by a spherical or grain-shaped semiconductor element for use in a solar cell. The method for the production of such a semiconductor element is characterized by the application of a conductive back contact layer onto a spherical or grain-shaped substrate core, by the application of a first precursor layer made of copper or copper gallium, by the application of a second precursor layer made of

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indium and by the reaction of the precursor layers with sulfur and/or selenium to form a I-III-VI compound semiconductor.

The reaction of the precursor layers takes place in the presence of selenium and/or sulfur and is referred to as selenization or sulfurization. These processes can be carried out in various ways with parameters that are coordinated with the given process. These include ...

1. A method for the production of a spherical or grain-shaped semiconductor element (11) for use in a solar cell, characterized by the following steps:

- application of a conductive back contact layer (30) onto a spherical or grain-shaped substrate core (20);
- application of a first precursor layer (40) made of copper or copper gallium;
- application of a second precursor layer (50) made of indium;
- reaction of the precursor layers (40) and (50) with sulfur and/or selenium to form a I-III-VI compound semiconductor, whereby the reaction of the layer structure (10) is carried out in a melt of the reaction element sulfur or selenium, or the reaction of the layer structure (10) is carried out in hydrogen compounds of the reaction element sulfur or selenium, whereby the reaction in hydrogen compounds is carried out at atmospheric pressure or at a pressure lower than atmospheric pressure.

2. The method according to claim 1, characterized in that the main constituent of the conductive back contact layer (30) is molybdenum.

3. The method according to claim 2, characterized in that the conductive back contact layer (30) contains up to 20% by weight of gallium in order to improve the adhesion.

4. The method according to one or more of the preceding claims, characterized in that the layers (30; 40; 50) are each applied by means of PVD or CVD methods.

5. The method according to one or more of the preceding claims, characterized in that a layer structure (10) comprising precursor layers (40; 50) is alloyed at a temperature of $T > 220^{\circ}\text{C}$ [$> 428^{\circ}\text{F}$] prior to the reaction to form a I-III-VI compound semiconductor.

6. The method according to one or more of the preceding claims, characterized in that a treatment with a KCN solution is carried out after the reaction of the layer structure (10) to form a I-III-VI compound semiconductor.

7. The method according to one or more of the preceding claims, characterized in that a buffer layer is deposited after the reaction of the layer structure (10) to form a I-III-VI compound semiconductor.

8. The method according to one or more of the preceding claims, characterized in that a high-resistance ZnO layer and a low-resistance ZnO layer are deposited after the reaction of the layer structure (10) to form a I-III-VI compound semiconductor.

9. The method according to one or both of the preceding claims 7 and 8, characterized in that the buffer layer and/or the high-resistance and the low-resistance layers are deposited by means of PVD or CVD methods.

10. A spherical or grain-shaped semiconductor element for use in solar cells, characterized in that the semiconductor element (11) has a spherical or grain-shaped substrate core (20) that consists of soda-lime glass and that is coated at least with one back contact layer (30) made of molybdenum and with one I-III-VI compound semiconductor.

11. The semiconductor element according to claim 10, characterized in that the diameter of the substrate core (20) is in the order of magnitude of 0.1 mm to 1 mm, especially approximately 0.2 mm.

12. The semiconductor element according to one or more of claims 10 and 11, characterized in that the thickness of the back contact layer (30) is in the order of magnitude of 0.1 μm to 1 μm .

13. The semiconductor element according to one or more of claims 10 to 12, characterized in that the I-III-VI compound semiconductor layer (60) consists of a compound from the group of the copper indium sulfides, copper indium diselenides, copper indium gallium sulfides or copper indium gallium diselenides.

14. The semiconductor element according to one or more of claims 10 to 13, characterized in that the thickness of the I-III-VI compound semiconductor layer (60) is in the order of magnitude of 1 μm to 3 μm .

15. The semiconductor element according to one or more of claims 10 to 14, characterized in that the semiconductor element (11) has a buffer layer above the I-III-VI compound semiconductor layer (60).

16. The semiconductor element according to claim 15, characterized in that the buffer layer consists of a material from the group comprising CdS, ZnS, ZnSe, ZnO, indium selenium compounds or indium sulfur compounds.

17. The semiconductor element according to one or both of claims 15 and 16, characterized in that the thickness of the buffer layer is in the order of magnitude of 20 nm to 200 nm.

18. The semiconductor element according to one or more of claims 10 to 17, characterized in that the semiconductor element has a high-resistance and a low-resistance ZnO layer above the I-III-VI compound semiconductor layer (60).

19. The semiconductor element according to claim 18, characterized in that the thickness of the high-resistance layer is in the order of magnitude of 10 nm to 100 nm, whereas the thickness of the low-resistance ZnO layer is in the order of magnitude of 0.1 μm to 2 μm .

20. The semiconductor element according to one or more of claims 10 to 19, characterized in that the semiconductor element (11) was produced by a method according to one or more of claims 1 to 9.

21. A method for the production of a solar cell having integrated spherical or grain-shaped semiconductor elements, characterized by the following features:

- incorporation of several spherical or grain-shaped semiconductor elements (11) into an insulating support layer (70), whereby the semiconductor elements (11) protrude from the surface of the support layer on at least one side of the support layer, and the semiconductor elements (11) each consist of a spherical or grain-shaped substrate core (20) that is coated at least with one conductive back contact layer (30) and with one I-III-VI compound semiconductor layer (60);
- removal of parts of the semiconductor elements (11) on one side of the support layer (70) so that a surface of the conductive back contact layer (30) of the semiconductor elements (11) is exposed;
- application of a back contact layer (80) onto the side of the support layer (70) on which parts of the semiconductor elements (11) have been removed; and
- application of a front contact layer (90) onto the side of the support layer (70) on which no semiconductor elements (11) have been removed.

22. The method according to claim 21, characterized in that, in addition to parts of the semiconductor elements (11), part of the support layer (70) is also removed.

23. The method according to one or both of claims 21 and 22, characterized in that the semiconductor elements (11) are applied onto the support layer (70) by means of scattering, dusting and/or printing and they are subsequently incorporated into the support layer.

24. The method according to one or more of claims 21 to 23, characterized in that the support layer (70) is configured as a matrix with recesses into which the semiconductor elements (11) are incorporated.

25. The method according to one or more of claims 21 to 24, characterized in that the semiconductor elements (11) are incorporated into the support layer (70) by means of a heating and/or pressing procedure.

26. The method according to one or more of claims 21 to 25, characterized in that the removal of the semiconductor elements (11) and/or of the support layer (70) is done by grinding, polishing, etching, thermal energy input and/or by photolithographic processes.

27. The method according to one or more of claims 21 to 26, characterized in that the back contact layer (80) and/or the front contact layer (90) are deposited by PVD or CVD methods or by other methods adapted to the material of the layer in question.

28. A solar cell having integrated spherical or grain-shaped semiconductor elements, characterized in that the solar cell has at least the following features:

- an insulating support layer (70) into which the spherical or grain-shaped semiconductor elements (11) are incorporated, whereby the semiconductor elements (11) protrude from the layer on at least one side of the support layer (70), and the semiconductor elements (11) each consist of a spherical or grain-shaped

substrate core (20) that is coated at least with one conductive back contact layer (30) and with one I-III-VI compound semiconductor layer;

- a back contact layer (80) on one side of the support layer (70), whereby several semiconductor elements (11) on this side of the support layer have a surface that is free of I-III-VI compound semiconductors; and
- a front contact layer (90) on the side of the support layer (70) on which the semiconductor elements (11) do not have a surface that is free of I-III-VI compound semiconductors.

29. The solar cell according to claim 28, characterized in that it is produced by means of a method according to one or more of claims 21 to 27.

30. The solar cell according to one or both of claims 28 and 29, characterized in that the insulating support layer (70) consists of a thermoplastic material.

31. The solar cell according to one or more of the preceding claims 28 to 30, characterized in that the support layer (10) consists of a polymer from the group of the epoxides, polycarbonates, polyesters, polyurethanes, polyacrylics and/or polyimides.

32. The solar cell according to one or more of the preceding claims 28 to 31, characterized in that the spherical or grain-shaped semiconductor elements (11) are semiconductor elements according to one or more of claims 10 to 20.

33. The solar cell according to one or more of claims 28 to 32, characterized in that the semiconductor elements (11) are coated with a I-III-VI compound semiconductor from the group of the copper indium diselenides, copper indium disulfides, copper indium gallium diselenides and copper indium gallium diselenide disulfides.

34. The solar cell according to one or more of claims 28 to 33, characterized in that the front contact layer (90) consists of a conductive material.

35. The solar cell according to claim 34, characterized in that the front contact layer (90) consists of a transparent conductive oxide (TCO).

36. The solar cell according to one or more of claims 28 to 35, characterized in that the back contact layer (80) consists of a conductive material.

37. The solar cell according to claim 36, characterized in that the back contact layer (80) consists of a metal, a transparent conductive oxide (TCO) or a polymer having conductive particles.

38. The solar cell according to claim 37, characterized in that the back contact layer (80) consists of a polymer from the group of the epoxy resins, polyurethanes and/or polyimides having conductive particles from a group comprising carbon, indium, nickel, molybdenum, iron, nickel chromium, silver, aluminum and/or the corresponding alloys or oxides.

39. The solar cell according to claim 38, characterized in that the back contact layer (80) consists of an intrinsic conductive polymer.

40. A photovoltaic module, characterized in that it has at least one solar cell according to one or more of claims 28 to 39.